The foraminiferal assemblages of the uppermost Kimmeridgian-Volgian succession of Western Siberia and their correlation potential

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ABSTRACT: The present study summarizes the data on the continuous stratigraphic sequence of foraminiferal assemblages from the Volgian deposits of the south-east of Western Siberia.

Microfaunal analyses of 650 core samples from 18 boreholes of Volgian deposits were performed. Eighty two foraminiferal species, identified from the samples, were combined into the Volgian assemblages. On the basis of these assemblages, four biostratigraphic units were established in the range of foraminiferal zones and foraminiferal beds with characteristic species. These biostratigraphic units correspond to the upper part of the Kimmeridgian/ lower part of the Volgian, the Middle Volgian (lowermost and uppermost beds), and the Upper Volgian. A detailed biostratigraphic analysis of the Volgian beds was carried out, which enabled a correlation scheme to be developed for major regions of Russia. West-Siberian foraminiferal assemblages were correlated with those of Europe and North America within the Panboreal Superrealm. The species composition of foraminiferal assemblages was analyzed, and correlatable species were established. This provided an opportunity to correlate coeval strata from Western Siberia, East European (Russian) Platform, northern territories of Siberia and Arctic Islands, Canada, Spitsbergen and England.

The possibility was established for correlating Volgian-Tithonian deposits of the Panboreal and Tethys-Panthalassa Superrealms through the Dnieper-Donets Basin where faunas of both southern and Boreal-Arctic types are met.

INTRODUCTION

During the last few decades, the stratigraphy of the uppermost Jurassic-lowermost Cretaceous (scope, sequences and position of the boundary) as well as the problems of correlation between the Volgian and Tithonian stages have been the subject of careful studies and discussion by the stratigraphers of the Mesozoic in Russia (Gerasimov and Mikhaylov 1966; Krymgolts 1982; Sey and Kalachyova 1997; Zakharov 1986). In 1996 the Volgian Stage was withdrawn from the General Stratigraphic Scale of Russia (it was transferred into the rank of a regional stage) and partly replaced with the Tithonian Stage by the Resolution of the Interdepartmental Stratigraphical Committee of Russia (1997). However, this did not solve the problem of correlation between the Volgian and Tithonian stages. The problem of identifying and mapping of the Boreal deposits of Tithonian age remains unresolved. On this basis the Volgian Stage is retained in the West Siberian Stratigraphical Scale

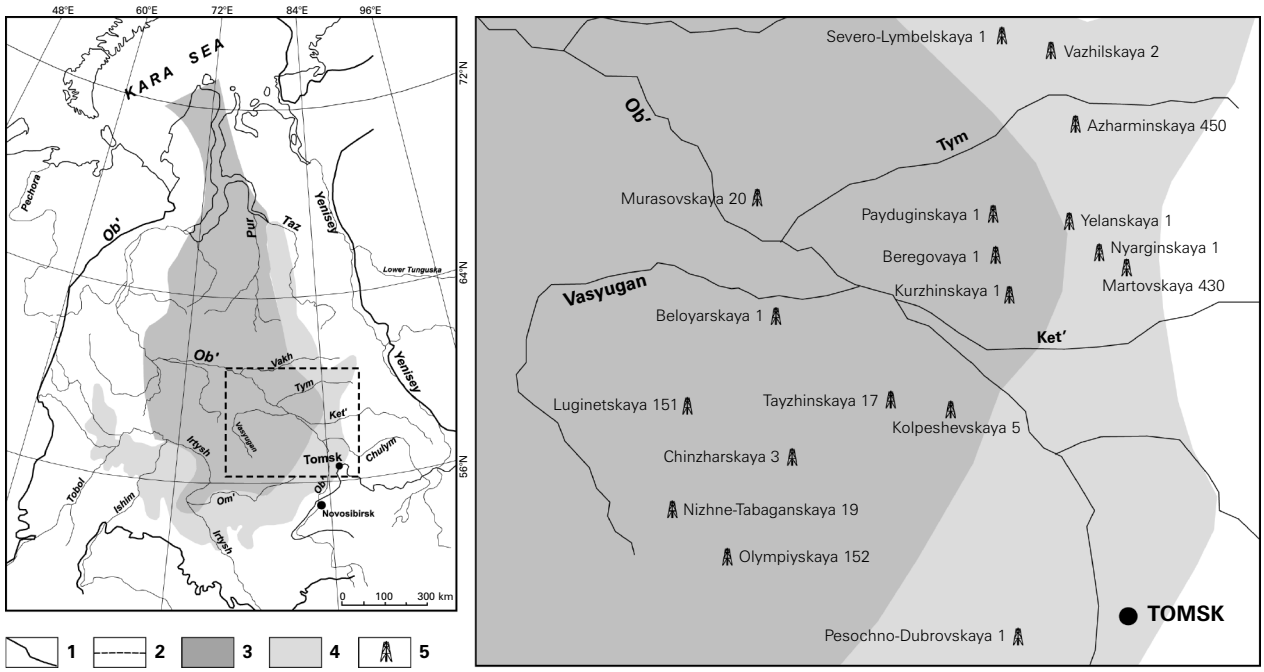

Fig. 1. Distribution of the Bazhenovskaya and Maryanovskaya formations and the location of studied sections: 1 – the approximate boundary of the West Siberian plain; 2 – studied area; 3 – the Bazhenvskaya formation; 4 – the Maryanovskaya formation; 5 – studied boreholes.

as the terminal Jurassic Stage, owing to the impossibility of the application of the new standard directly to the Boreal sections. The difficulties in comparison between the Regional Scale and the Standard one arise not only for the different ammonite zonations, but also in correlating the ammonite zones with West-Siberian foraminiferal zones.

The Upper Jurassic – Lower Cretaceous zones based on ammonites remain the basis for the current stratigraphic zonation of these deposits with only minor changes and refinement. Although ammonites remain the most reliable and stratigraphically valuable group of the fossils, of great interest and of potential stratigraphic significance, in the cores are the data on the composition and nature of changes in foraminiferal assemblages. The evolution of the benthic foraminifera bears a non-uniform and non-equivalent character in different genera and families, and it is characterized by considerable spatial distribution which resulted from their high euryfacial ability (they are adaptable to dwell in varying physico-geographical conditions). Nevertheless, currently they are a useful tool both for detailed stratigraphy and for interregional correlation. The basis for establishing foraminiferal zones is a succession of foraminiferal assemblages which reflects both alteration in facies-and-ecological settings of sedimentation in a basin and the stages of evolution of this group of organisms. The benthic foraminifera were of the broadest distribution in the Late Jurassic – Early Cretaceous basins of the Panboreal Superrealm: from Western and Eastern Europe to the shelf zones of the Arctic seas, from Western and Eastern Siberia to the Canadian Arctic Islands and the north of Canada.

The Volgian Stage deposits are characterized by the significant diversity in the rock compositions and thickness, as well as by the extremely peculiar fauna. Complex investigations of core samples from numerous boreholes penetrating the territory of Western Siberia (Fig. 1) allowed the differentiation of the Boreal Volgian Stage and the solving the theoretical problems on the Upper Jurassic stratigraphy for these unexposed deposits.

BIOSTRATIGRAPHY

In the last few decades the numerous publications by leading Russian stratigraphers of the West-Siberian Jurassic – Lower Cretaceous have summarized material on the stratigraphic range of certain strata and members; the stratigraphic units have been comprehensively characterized in paleontological aspects; the Late Jurassic – Early Cretaceous essential paleogeographic settings and facies have

been reconstructed (Kozyreva 1957; Mesezhnikov and Shulgina 1961; Saks *et al.* 1963; Vyshemirskiy 1986). The regional stratigraphic chart of the Upper Jurassic – lowermost Cretaceous West-Siberian deposits includes more than a hundred local stratigraphic units (suites, members, strata) comprising three horizons: the Vasyuganian (Callovian/Oxfordian), Georgievskian (Kimmeridgian) and Bazhenovskian (the Volgian/Ryazanian stages) (*Resolution of the 5th…* 1991). It should be remembered that the term "horizon" according to the Stratigraphic Code of Russia is the "basic taxonomic (hierarchic, rank) unit of regional subdivisions performing a correlational function within the limits of its geographical distribution." It corresponds thus to a regional stage in the stratigraphic codes of other countries.

Biostratigraphic investigations of the West-Siberian Jurassic – lowermost Cretaceous deposits have always been based on the presence of the microfauna within them and especially on the foraminifera. We consider the foraminiferal assemblages to be of primary significance for these unexposed deposits, because finds of ammonites are so scarce that they may be used only as a control for correlation with the deposits containing these fossils in the exposures in the north of Siberia, the Subarctic Urals and Mangyshlak. Nevertheless, the sequence of the widespread foraminiferal assemblages established promotes the determination of the chronostratigraphical boundaries within the deposits studied. For example, in Western Siberia the Volgian/Ryazanian boundary is found within the homogenous shales of the Bazhenovskaya formation (a local stratigraphic unit subordinated to a horizon) and the shaly silty deposits of the Maryanovskaya formation. This boundary can at present be traced neither from lithologic characteristics nor in logs and is established only with the help of the foraminiferal succession.

In addition, the material of the faunal orthostratigraphic groups collected was used for the paleontological characterization of some borehole sections. The correlation of faunas belonging to different biochores was performed with the use of intermediate foraminiferal assemblages including species met simultaneously in different biochores. The correlation was controlled by the ammonite scale, or, in case of the absence of ammonites, with the help of other orthostratigraphic faunal groups, for example, the bivalve *Buchia*.

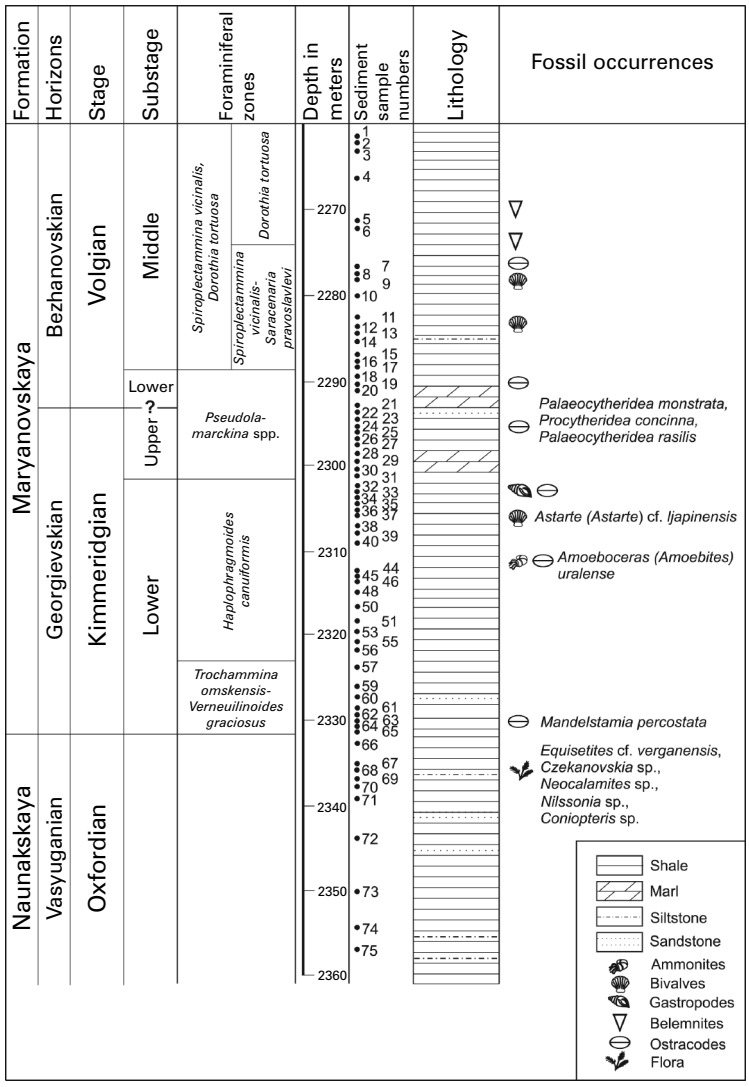

Fig. 2. The studied section from the Nyarginskaya-1 borehole.

Volgian Stage

Lower Volgian Substage

Pseudolamarckina voliaensis Zone (Fig. 4)

The *P. voliaensis* assemblage was established by Dain (1972) within the lowermost sediments, dated as Volgian age by ammonites (Mesezhnikov 1984; Saks 1976) in the basins of many rivers of the Arctic and Subarctic Urals. Along with the abundance of *P. voliaensis* Dain, there occur isolated *Nodosaria*

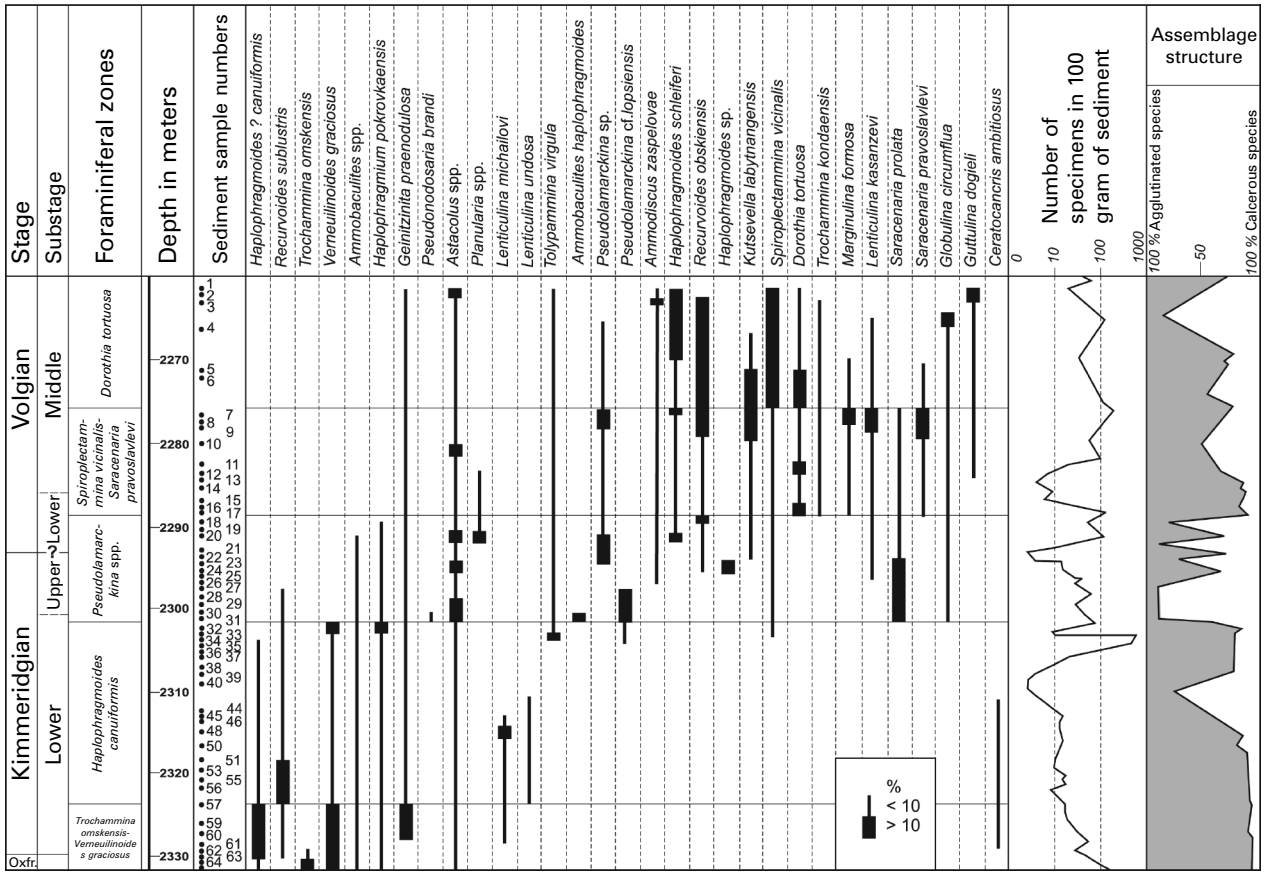

Fig. 3. Stratigraphic distribution of foraminiferal species and zonal subdivision of Kimmeridgian to Volgian deposits of the Nyarginskaya-1 borehole section.

tubifera Reuss, *Geinitzinita nodulosa* (Furssenko and Poljenova), *Marginulina* ex gr. *striatocostata* Reuss, *Globulina circumflua* Dain, *Ceratolamarckina* ex gr. *zatonica* (Mjatliuk) and others. In the south-east of Western Siberia, an assemblage with *Pseudolamarckina* sp. similar to *P. voliaensis* has been established by us in the Nyarginskaya-1 borehole. This borehole section (Figs 2, 3) is typical of the Volgian deposits of this region. Previously, the occurrence of beds with a similar microfauna was reported by Kozyreva (1957) for the Beloyarskaya key borehole.

Within the Nyarginskian type section (Fig. 3), the following two types of deposits with *Pseudolamarckina* have been established: 1 – Upper Kimmeridgian deposits containing the *P. lopsiensis* assemblage and corresponding to the *P. lopsiensis* Zone (Fig. 4), and 2 – superjacent deposits with *Pseudolamarckina* sp. These latter deposits are supposed to be correlatable with Subarctic Uralian beds containing the *P. voliaensis* assemblage. The species of the genus *Pseudolamarckina* from the south-eastern areas are somewhat different from those described by Dain (1972) from the Subarctic Urals. That is why the correlation between the coeval beds is based on the similar accompanying species, such as *Recurvoides sublustris* Dain, *R. obskensis* Romanova, *Lenticulina jatriensis* Dain, *Marginulina complacida* Putrja, *Astacolus inflatiformis* Dain, *Vaginulinopsis flacidiformis* Putrja, *Planularia mesezhnicovi* Dain, *Ichtiolaria tjumenica* Tylkina, and others. The distinct boundary between the Kimmeridgian and Volgian stages has not been established in the area studied.

Middle Volgian Substage
Spiroplectammina vicinalis - Dorothia tortuosa Zone (Fig. 4)

Numerous agglutinated foraminiferal species are distributed over this zone, with *Spiroplectammina* and *Ammobaculites* predominating. Among secreted calcareous forms, ornate *Marginulina* (having test surface ornamentation) as well as diverse *Lenticulina* are particulary abundant.

The taxonomy of the foraminiferal assemblages are not identical in the different areas of Western Siberia. In Preuralia, two subassemblages are established in the section of the *Spiroplectammina vicinalis - Dorothia tortuosa* assemblage: the *Spiroplectammina vicinalis - Saracenaria pravoslavlevi* sub-assemblage (the lower one) and the *Dorothia tortuosa* subassemblage (the upper one). In the shallow facies of the Taimyr Peninsular, the *Lenticulina djabakaensis - Citharina nabliuma* assemblage has been established with Nodosariidae in abundance (Grigelis 1982).

The *Spiroplectammina vicinalis - Dorothia tortuosa* assemblage of the Nyarginskian type section in the south-east of Western Siberia (Figs 2, 3) is reliably separated into two subassemblages. The lower *Spiroplectammina vicinalis - Saracenaria pravoslavlevi* subassemblage is characterized by the predominance of such Nodosariidae as *Lenticulina initabilis* (Zaspelova), *L. sosvaensis* Dain, *Astacolus* sp., *Marginulina striatocostata* (Reuss), *M. formosa* Mjatliuk, *Saracenaria pravoslavlevi* Furssenko and Poljenova, *S. prolata* K. Kuznetsova, and others. There is no such a species variety among the agglutinated forms. Along with the zone species, of common occurrence are *Evolutinella schleiferi* (Scharovskaja), *Recurvoides obskensis* Romanova, *Dorothia tortuosa* Dain and Komissarenko, *Spiroplectammina vicinalis* Dain, and others.

The upper *Dorothia tortuosa* subassemblage from the Middle Volgian Substage is characterized by the predominance of agglutinated species: *Reophax adaptatus* Dain, *Evolutinella volossatovi* Scharovskaja, *Recurvoides stschekuriensis* Dain, *Haplophragmium elongatum* Dain, *Spiroplectammina vicinalis* Dain, *Dorothia tortuosa* Dain and Komissarenko.

The lower boundary of the *Spiroplectammina vicinalis - Dorothia tortuosa* assemblage is established by the mass occurrence of the index species and *Marginulina* showing surface ornamentation. (It should be noted here that the major part of the Upper Jurassic *Marginulina* species of Western Siberia is devoid of elements forming surface sculpture, that is they are smooth-walled). The numerous characteristic species disappear near the upper boundary. The *Spiroplectammina vicinalis - Dorothia tortuosa* assemblage is traced throughout the Canadian Arctic Islands

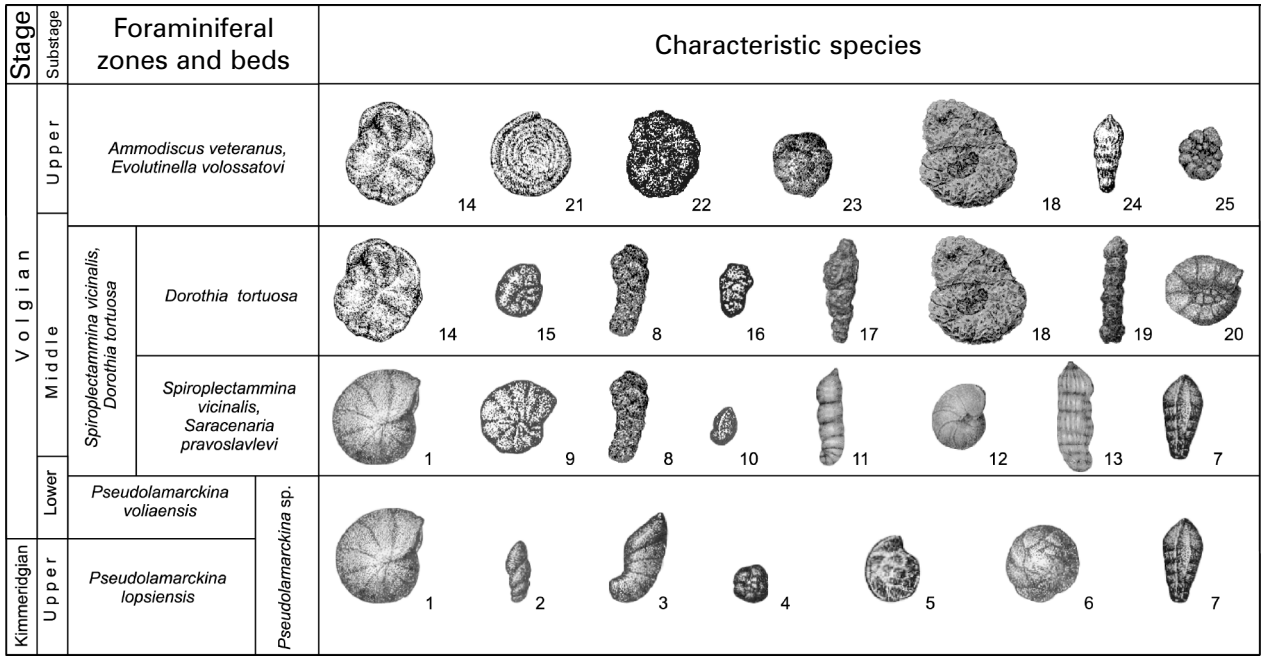

Fig. 4. Zonation of West Siberian Volgian and characteristic species of the Volgian foraminiferal assemblages: 1 – *Lenticulina initabilis* Zespelova; 2 – *Vaginulina angusta* Putrja; 3 – *Vaginulinopsis vulgatus porectus* Putrja; 4 – *Ceratolamarckina* ex gr. *zatonica* (Mjatliuk); 5 – *Pseudolamarckina* cf. *voliaensis* Dain; 6 – *Pseudolamarckina* cf. *lopsiensis* Dain; 7 – *Geinitzinita praenodulosa* Dain; 8 – *Spiroplectammina vicinalis* Dain; 9 – *Haplophragmoides schleiferi* Scharovskaja; 10 – *Saracenaria pravoslavlevi* Furssenko and Poljenova; 11 – *Marginulina formosa* Mjatliuk; 12 – *Lenticulina sosvaensis* Dain; 13 – *Marginulina striatocostata* Reuss; 14 – *Evolutinella volossatovi* Scharovskaja; 15 – *Recurvoides praeobskiensis* Dain; 16 – *Dorothia tortuosa* Dain and Komissarenko; 17 – *Reophax adaptatus* Dain; 18 – *Kutzevella labythnangensis* (Dain); 19 – *Haplophragmium elongatum* Dain; 20 – *Recurvoides stschekuriensis* Dain; 21 – *Ammodiscus veteranus* Kosyreva; 22 – *Evolutinella emeljanzevi* Schleifer; 23 – *Trochammina rosacea* Zespelova; 24 – *Marginulina complacida* Putrja; 25 – *Trochammina kondaensis* Levina.

Boreal-Atlantic area									Arctic area					
Boreal-Atlantic area				Boreal-Atlantic area					Boreal-Atlantic area					
Southern England				Russian platform					Spitsbergen			Barents Sea Shelf		
Cope *et al.* 1969; Casey 1973			Kuznetsova 1979	Gerasimov and Mikhailov 1966; Mesezhnikov 1984				Biostratigraphy of Upper Jurassic deposits ... 1982; Yakovleva 1979	Basov 1982; Løfaldli and Nagy 1983			Berner *et al.* 2001		
Stage	**Substage**	**Ammonite zones**	**Foraminiferal zones and beds**	**Stage**	**Substage**	**Ammonite zones**		**Foraminiferal zones and beds**	**Stage**	**Substage**	**Foraminiferal zones and beds**	**Stage**	**Substage**	**Foraminiferal zones and beds**
Ryazanian		Hectoroceras kochi	Not established	Ryazanian		Riasanites rjasanensis		*Lenticulina crassa, Marginulinopsis rjasanensis*	Ryazanian		*Gaudryina gerkei, Recurvoides obskiensis*	Ryazanian		*Calyptammina praegyroidiniformis, Recurvoides obskiensis*
		Praetollia runctoni												
Volgian	Upper	Subcraspedites lamplughi	Not established	Volgian	Upper	Craspedites nodiger		*Lenticulina munsteri*	Volgian	Upper	*Ammodiscus veteranus, Evolutinella emeljanzevi*	Volgian	Upper	
		Subcraspedites (S.) preplicomphalus												
		Subcraspedites (Swinnertonia) primitivus				Craspedites subditus		*Astacolus aquilonicus, Marginulina impropria*						
						Kachpurites fulgens		*Placopsilina* sp., *Astacolus polyhymnius*						
Portlandian		Paracraspedites oppressus	*Lenticulina nuda*		Middle	Epivirgatites nikitini		*Spirofrondicularia rhabdogonioides, Lenticulina oligostegia*		Middle	*Ammodiscus veteranus, Trochammina rosacea*		Middle	*Trochammina omskensis*
		Titanites giganteus	Not established											
		Credonites gorei				Virgatites virgatus	Virgatites rossanovi	*Lenticulina ponderosa, Flabellammina lidiae*						
		Progalbanites albani	*Lenticulina ornatissima, Vaginulinopsis rectus*				Virgatites virgatus							
			Spiroplectammina inderica, Saracenaria kasanzevi			Dorsoplanites panderi	Zaraiskites zaraiskensis	*Lenticulina infravolgaensis, Saracenaria pravoslavlevi*						
Kimmeridgian	Upper	Pavlovia rotunda					Pavlovia pavlovi							
		Pavlovia pallasioides												
		Pectinatites pectinatus	*Marginulinita pyramidalis*		Lower	Ilovaiskya pseudoscythica		*Marginulinita pyramidalis, Lenticulina undorica*		Lower	Not established		Lower	
		Arkellites hudlestoni	*Lenticulina infravolgensis anglica, Planularia mariae*			Ilovaiskya sokolovi		*Pseudolamarckina bieleckae-Verneuilinoides kirillae*						
		Virgatosphinctoides wheatleyensis												
		Virgatosphinctoides slitulus												
		Virgato-sphinctoides elegans				Ilovaiskya klimovi								

Fig. 5. Zonal sequence and correlation of Volgian deposits within the Boreal belt based on Foraminifera.

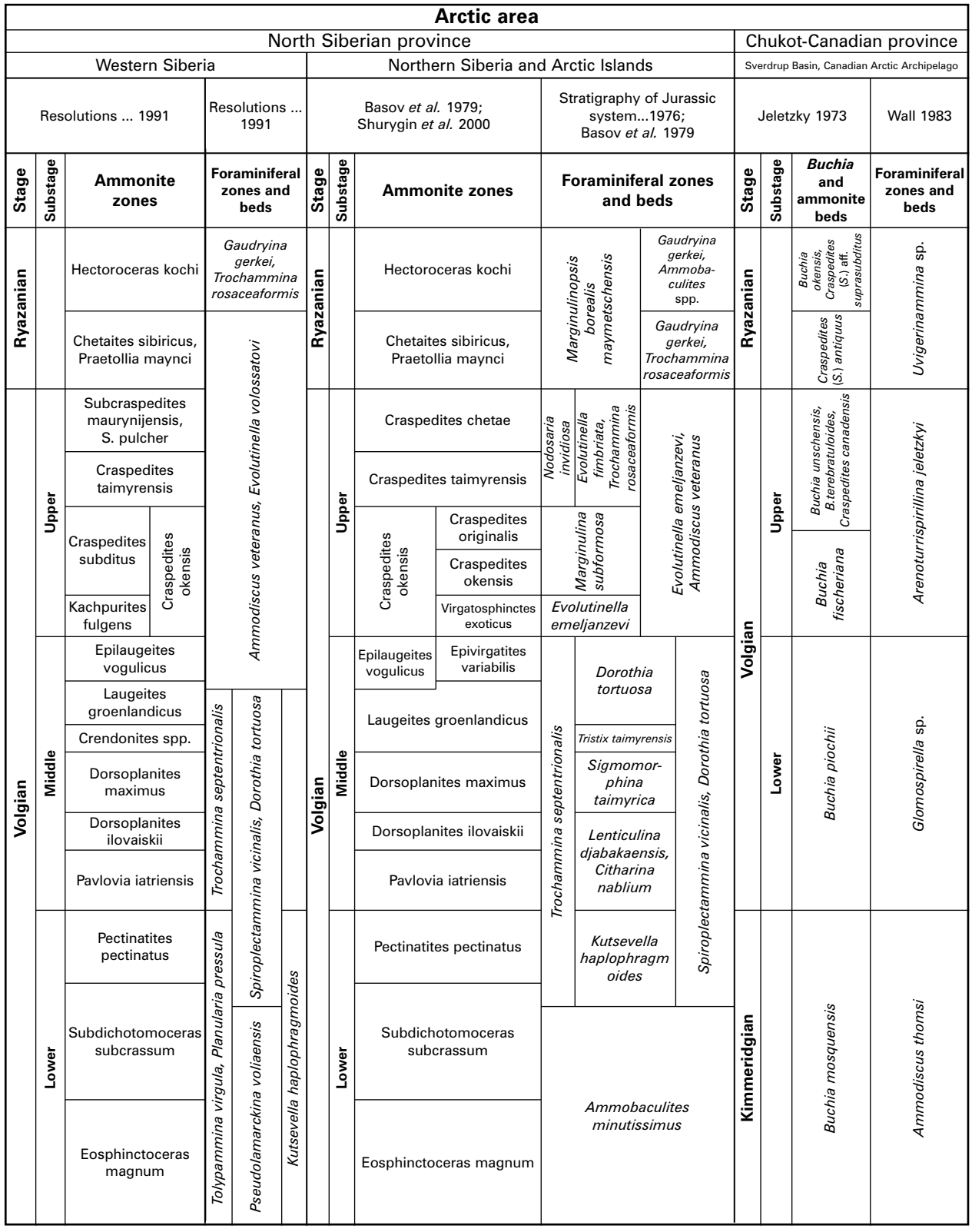

Fig. 6. Zonal sequence and correlation of Volgian deposits within the Boreal belt based on Foraminifera.

(the Deer Bay Formation) and the Baltic Coast in Europe *via* Western Siberia and Northern Kamchatka as far as the Alaska Peninsula (Grigelis 1982; Kuznetsova 1978, 1979; Løfaldli and Nagy 1983; Wall 1983). This assemblage serves as the basis for the reliable correlation of their enclosing deposits within the whole Panboreal Superrealm.

Upper Volgian Substage
Ammodiscus veteranus - Evolutinella volossatovi Zone (Fig. 4)

The *Ammodiscus veteranus - Evolutinella volossatovi* assemblage was established by Komissarenko and Levina (1968). It was subsequently traced in all the Mesozoic basins in the north of Siberia and in the Barents Sea shelf (Sokolov 1991). The thickness of the deposits of the Bazhenovskian horizon enclosing this assemblage changes greatly, from 5 m to 170 m towards the marginal lands of Western Siberia. The agglutinated species occur in abundance, with *Evolutinella* predominating within the marginal sites; the secreted *Lenticulina* and *Polimorphina* constitute the majority within the upper part of the foraminiferal zone. This assemblage contains over 40 foraminiferal species of 9 families. The percentage of the index species *Ammodiscus veteranus* Kosyreva and *Evolutinella volossatovi* Scharovskaja makes up about 70%. Along with the abundance of the index species, *E. emeljanzevi* (Schleifer), *E. schleiferi* (Scharovskaja), *Recurvoides praeobskensis* Romanova, *Kutzevella labythnangensis* Dain, *Trochammina rosazea* Zaspelova, *T. misinovi* Levina, *T. kondaensis* Levina are of frequent occurrence everywhere throughout Western Siberia (Fig. 4). As a rule, in the Upper Volgian, foraminifera occur within the near-shore facies.

Numerous papers were devoted to the dating of the *Ammodiscus veteranus - Evolutinella volossatovi* assemblage (Ivanova 1973; Komissarenko and Levina 1968; Sharovskaya 1968). This foraminiferal assemblage often occurs together with Upper Volgian ammonites in Western and Eastern Siberia. In the area studied, the age of the *Ammodiscus veteranus - Evolutinella volossatovi* assemblage was confirmed by the finds of the ammonite *Kachpurites subfulgens* (Nikitin) from the borehole Kolpashevskaya-5 (Vyshemirskiy 1986).

Within the deposits at the Volgian/Ryazanian boundary of Western Siberia, the composition of benthic foraminiferal assemblages is significantly variable. The Ryazanian assemblages are distributed within the diverse facies of the Bazhenovskian horizon and distinguished by the presence of more compact tests. The *Trochammina rosaceaformis* assemblage is most often detected; it occurs at the base of the Ryazanian and was described from the Azharminskian District (Podobina *et al.* 1982). The abundance of the index species is characteristic of this assemblage, but the representatives of the genera *Recurvoides, Evolutinella, Ammobaculites, Lenticulina* are rarely found. Another *Gaudryina gerkei* assemblage was reported from the eastern part of Western Siberia (Sharovskaya 1968). About 25 species assigned to 13 genera make up this widely known assemblage. The most characteristic species are as follows: *Haplophragmoides fimbriatus* Scharovskaja, *Ammobaculites* ex gr. *fontinensis* Terquem, *Orientalia baccula* (Schleifer), *Marginulina zaspelovae* Romanova and *Globulina chetaensis berriassica* Basov. The stratigraphic position of this foraminiferal assemblage was established by its common occurrence with the Ryazanian ammonite *Surites spasskensis* (Nikitin) in the Subarctic Urals (Mesezhnikov and Shulgina 1961).

The Volgian/Ryazanian boundary established by us at the change of assemblages occurs within the uniform clay rocks of the Bazhenovskian horizon. It is traceable by the disappearance of Late Volgian foraminifera of the *Ammodiscus veteranus* and *Evolutinella volossatovi* assemblage and by the emergence of Ryazanian foraminifera (*Trochammina rosaceaformis* assemblage).

CORRELATION BETWEEN FORAMINIFERAL ASSEMBLAGES OF THE PANBOREAL SUPERREALM

Volgian foraminifera have an extremely broad distribution within the Panboreal Superrealm: the Late Jurassic transgression reached its maximum during this age. Numerous investigations resulted in revealing the traces of the Kimmeridgian-Volgian transgression in the form of black-shaly high-bituminous rocks on the coast of the Laptev Sea (Bogolepov 1983), on the shelf of the Barents Sea, on Franz Josef Land and Spitsbergen (Basov *et al.* 1997; Nagy and Basov 1998; Zakharov *et al.* 1998), in the north of Scandinavia (Pchelina 1967), in the North Sea (Klein and Mutterlose 2001), in southern England (Jenkins 2000) and in the north of Greenland (Berner *et al.* 2001). Numerous publications

were devoted to the Volgian foraminiferal zone correlation within the Arctic and Boreal-Atlantic Realms (Kuznetsova 1978, 1979; Kuznetsova *et al.* 2001; Basov *et al*. 1979).

The *Pseudolamarckina voliaensis* Zone was established within the Lower Substage of the Volgian Stage in the Subarctic Urals and Western Siberia. The species composition of the assemblage seems to be dominated by *Ceratobulimina* along with *Epistomina* and is well represented on the East-European (Russian) Platform. Two assemblages were established in the stratotype section of the Volgian Stage: the lower one (*Pseudolamarckina polonica* assemblage) reflecting the final stage of development in *Epistomina* and *Ceratobulimina*, and the upper one (*Marginulinita pyramidalis* assemblage) characterized by the appearance of Middle Volgian forms in foraminiferal assemblages (Basov *et al.* 1979). The Early Volgian foraminifera of the Ust'-Yenisey district (situated near the Yenisey River estuary) are represented by the accumulation of individuals of a single species, *Ammobaculites minutissimus* Scharovskaja (Sharovskaya 1968) (Fig. 6).

The acme of both agglutinated and calcareous foraminifera is typical of the Middle Volgian age of the Panboreal Superrealm. The *Spiroplectammina vicinalis - Dorothia tortuosa* Zone, including two foraminiferal subassemblages, has been established from the Middle Substage of the Volgian Stage. The lower *Spiroplectammina vicinalis - Saracenaria pravoslavlevi* subassemblage is closely matched by abundant and diverse assemblages from the Pechora Basin; the latter are comparable to the Middle Volgian assemblages from the north of Middle Siberia. The systematic composition of the calcareous foraminifera of the foraminiferal assemblages of the Pechora Basin is similar to that of Siberian ones, whereas that of their agglutinated representatives is different. The distinctions are manifested as the abundance of the species *Dorothia tortuosa* Dain and Komissarenko in the Pechora Basin and that of the species *Spiroplectammina vicinalis* Dain in the East-Siberian Platform and West-Siberian Plain (Saks 1976).

The Middle Volgian *Trochammina septentrionalis* assemblage occurs in the Nordvikskian district of the Ust'-Yenisey depression (Saks *et al.* 1963). The *T. septentrionalis* assemblage of the Yenisey-Khatanga Basin is well correlatable with that of the Middle Volgian deposits of the West-Siberian Platform (Komissarenko and Tylkina 1977). The Middle Volgian assemblages have been reported from the Western Spitsbergen sections and are, as a whole, similar to the Pechora ones (Pchelina 1967) in their taxonomy, but display a lower diversity and abundance of species. In southern Spitsbergen, the Middle Volgian foraminiferal assemblage has also been reported from the upper part of the Agardhfjellet Member of the Janusfjellet Formation (Løfaldli and Nagy 1983).

Assemblages of quite different composition have been recovered from the Middle Volgian deposits of Taimyr where littoral, facies are developed (Ivanova 1967). The *Lenticulina djabakaensis - Citharina nabliuma* assemblage was established here. It is characterized by the abundance of the calcareous foraminifera *Nodosaria* and *Polimorphina.* A number of European forms are among them: representatives of the genera *Citharina, Paradentalina, Spirofrondicularia,* and the species *Tristix temirica* Dain, *Geinitzinita penicilium* (Furssenko and Poljenova), *Guttulina dogieli* Dain, and others (Ivanova 1967).

The West-Siberian Middle Volgian upper assemblage of *Dorothia tortuosa* differing in species composition from the lower one was recovered from the same stratigraphic level as the *Spirofrondicularia rhabdogonioides - Lenticulina oligosteria* assemblage established on the Russian Platform and consisting principally of Nodosariidae of Cretaceous aspect (Basov *et al.* 1979).

Late Volgian foraminifera occur almost everywhere throughout the Panboreal Superrealm. In Western Siberia, the foraminiferal zone of the Upper Volgian Substage is characterized by an agglutinated foraminiferal assemblage with *Ammodiscus veteranus* and *Evolutinella volossatovi.* A similar assemblage occurs in the north of Siberia and in the Arctic Isles; however the species *Evolutinella emeljanzevi* (Schleifer) predominates. Assemblages possessing a composition similar to the above-mentioned ones have also been reported from the Upper Substage of the Spitsbergen Volgian Stage (Løfaldli and Nagy 1983; Pchelina 1967). The deposits of more shallow facies of the north of Siberia yield two assemblages: *Marginulina subformosa* and *Nodosaria invidiosa*. Both assemblages are characterized by the predominance of the Nodosariidae. These deposits are correlatable to strata with the *Bullopora vivejae* assemblage from the Pechora region. The assemblage is composed of agglutinated foraminifera and the secreted calcareous Nodosariidae, both characteristic of the Late Volgian of Siberia and of the

Russian Platform. The following zones have been established within the Upper Substage of the Volgian Stage on the Russian Platform: the lower *Placopsilina* sp. Zone containing the impoverished Nodosariidae assemblage; the intermediate *Astacolus aquilonicus* Zone with the abundant and peculiar community of Nodosariidae and Polimorphinida, and the uppermost *Lenticulina muensteri* Zone also containing the impoverished Nodosariidae assemblage (Basov *et al.* 1979).

The *Lenticulina crassa* - *Marginulinopsis rjasanensis* assemblage (Yakovleva 1979) is established in the lowermost Ryazanian of the Russian Platform; in the Pechora region and in Siberia different assemblages occur. However, they have a feature in common: they are similar to the Late Volgian assemblages characteristic of the Panboreal Superrealm (Basov *et al.* 1979). In Spitsbergen, the Ryazanian foraminiferal assemblages occur in grey argillaceous shales of the Rurikfjellet Member of the Janusfjellet Formation (Løfaldli and Nagy 1983). The Spitsbergen foraminiferal communities are similar in their composition to the Ryazanian *Gaudryina gerkei* and *Trochammina rosaceaformis* assemblages from the north of Siberia.

The studies by Kuznetsova (1978, 1979) have proved that the Lower/Middle Volgian deposits of the two different paleobiogeographical provinces of the Boreal-Atlantic Realm (East-European Volgian Province and West-European Portlandian Province) are reliably correlatable. This conclusion was made by this scientist on the basis of the material which she had gathered during the 16-year investigations on fauna from Russian Platform and Poland, from the Kimmeridgian, Portlandian and "Purbeckian" stratotype sections in England, and Tithonian and Berriasian ones in France. These investigations were reported in the comprehensive Russian monograph by Kuznetsova (1979). The correlation between the Volgian deposits of the Russian Platform (the Moscow Syneclise) and the Kimmeridgian, Portlandian and "Purbeckian" stratotype sections of South England showed the considerable coincidence of common sequences of foraminiferal assemblage, their volumes and species composition. The upper part of the Kimmeridge Clay is subdivided by Kuznetsova (1979) into two assemblages: *Lenticulina infravolgensis anglica* - *Planularia mariae* and *Marginulinita pyramidalis* (Fig. 5). All the characteristic species of the English foraminiferal assemblages, such as *Lenticulina undorica* K. Kuznetsova, *Planularia mariae* K. Kuznetsova, *Conorboides propatulus* Dain, *Geinitzinita nodulosa* (Furssenko and Poljenova), *Pseudolamarckina polonica* (Bielecka and Pożaryski), *Astacolus quinquecostatus* K. Kuznetsova, *Marginulinita pyramidalis* (Koch), are also present in the *Pseudolamarckina polonica* and *Marginulinita pyramidalis* assemblages from the Volgian stratotype section of the Russian Platform. The *Lenticulina ornatissima* - *Saracenaria kasanzevi*, *Lenticulina ponderosa* and *Lenticulina oligostegia* - *Astacolus mosquensis* assemblages have been established on the basis of calcareous foraminiferal forms within the Middle Substage of the Volgian Stage of the Russian Platform (Kuznetsova 1978). Three English assemblages correspond to this range: the *Spiroplectammina inderica* - *Saracenaria kasanzevi* assemblage, the *Lenticulina ornatissima* - *Vaginulinopsis rectus* assemblage and the *Lenticulina nuda* assemblage (Fig. 5). The following species are common for both regions: *Ammobaculites extentus* Dain, *Quinqueloculina egmontensis* Lloyd, *Spiroplectammina inderica* Furssenko, *Lenticulina dilucida* Dain, *L. biexcavata* (Mjatliuk), *L. vistulae* (Bielecka and Pożaryski), *L. ornatissima* (Furssenko and Poljenova), *L. infravolgensis* (Mjatliuk), *L. nuda* (Reuss), *Sigmoilinita subpanda* (Lloyd), *Saracenaria prolata* K. Kuznetsova, *S. ilovaiskii* (Furssenko), *S. pravoslavlevi* Furssenko and Poljenova, *S. kasanzevi* (Furssenko and Poljenova), *Marginulina orthogona* K. Kuznetsova, *Citharinella uhligi* (Furssenko and Poljenova), *Astacolus obligostegia* (Reuss) and *Vaginulinopsis rectus* (K. Kuznetsova). It should be noted that commencing with the middle part of the Middle Volgian Substage, the species compositions of the foraminiferal assemblages are somewhat different. Foraminiferal assemblages have not been established within the equivalents of the Upper Volgian Substage in England for lack of foraminifera (Fig. 5).

Volgian deposits of the Western Hemisphere characterized by foraminifera have been found within the Sverdrup Basin of the Canadian Arctic Islands (Wall 1983). Within the Volgian Stage, Wall (1983) established the *Glomospirella* sp. and *Arenoturrispirillina jeletzkyi* assemblages (Fig. 6). The *Glomospirella* sp. assemblage occurring within the top of the Awingak Formation was dated as Early Volgian (it corresponds to the Middle Volgian of the standard Boreal stratigraphic scale). The taxonomy of this foraminiferal assemblage was only determined up to the genus level: *Glomospirella* sp., *Reophax* sp., *Haplophragmoides* sp.,

Evolutinella sp., *Ammobaculites* sp., *Arenobulimina* sp. Of the greatest interest is the Late Volgian *Arenoturrispirillina jeletzkyi* assemblage occurring at the base of the Deer Bay Formation reported by Wall (1983). This assemblage is more diverse in taxonomy. Besides the index species, the following species are typical here: *Ammodiscus* cf. *orbis* Lalicker, *Haplophragmoides* cf. *canui* Cushman, *Cribrostomoides goodenoughensis* (Chamney), *Recurvoides* sp., *Lituotuba* sp., *Ammobaculites* sp., *Haplophragmium* cf. *pokrovkaensis* Kosyreva, *Trochammina* cf. *elevata* Kosyreva, *T. gryci* Tappan, *T.* cf. *misinovi* Levina, *Verneuilina anglica* Cushman, *Gaudryina milleri* Tappan, *G.* sp., *Orientalia* sp., *Geinitzinita* cf. *nodulosa* (Furssenko and Poljenova), *Lenticulina* cf. *kolvensis* E. Ivanova, *Marginulinopsis striatocostata* (Reuss). The composition of this assemblage is closely similar to that of the coeval assemblages from Western Siberia. The comparison of descriptions and depictions of foraminifera from the reports by Wall (1983) and Bulynnikova *et al.* (1990) enabled us to make the assumption that the name of the index species *Arenoturrispirillina jeletzkyi* Chamney (in Wall 1983) may be a synonym of *Arenoturrispirillina phiala* Kosyreva (in Bulynnikova *et al.* 1990) occurring in the Upper Volgian of Western Siberia.

In the upper part of the Deer Bay Formation, the Berriasian – Valanginian *Uvigerinammina* sp. assemblage (Wall 1983) has been discovered. The age of this assemblage is undoubtedly indicated by the occurrence of the Ryazanian *Buchia okensis* (Pavlow), *Pseudocraspedites* aff. *anglicus*, and the Early/Middle Valanginian *Tollia* sp., *Temnoptychites* sp. The taxonomy of the *Uvigerinammina* sp. assemblage from the Deer Bay Formation exhibits considerable similarity with that of the Late Volgian/Early Ryazanian assemblages from Western Siberia. Thus, for example, *Ammodiscus veteranus* Kosyreva and *Trochammina rosacea* Zaspelova are common for the both areas. However, these species from the Canadian Arctic Islands are of somewhat later occurrence (Ryazanian/Valanginian) than species from Western Siberia: thus, *Ammodiscus veteranus* Kosyreva from Western Siberia, the northern part of Central Siberia and from the Barents Sea shelf is not detected above the Chetaites sibiricus Zone – Hectoroceras kochi Zone (the lower part of the Ryazanian), whereas *Trochammina rosacea* Zaspelova is distributed within the Upper Volgian Substage of Western Siberia and in the north of Central Siberia. The higher stratigraphic position and the later age of the upper boundary of the species distribution range within the Canadian Arctic Archipelago in comparison with Western Siberia may result from species migration through the Boreal-Atlantic Basin westwards, as the North Atlantic was expanding. Consequently, the considerable similarity in the taxonomy of North-Canadian and West-Siberian foraminiferal assemblages allows as well the Volgian deposits of the Chukotka-Canadian and North-Siberian provinces to be reliably correlated.

CORRELATION BETWEEN FORAMINIFERAL ASSEMBLAGES OF THE PANBOREAL AND TETHYS-PANTHALASSA SUPERREALMS

In correlating the Volgian-Tithonian deposits of the Panboreal and Tethys-Panthalassa Superrealms, comparison between Boreal and Tethyan faunas involves difficulties because of the differences between their taxonomy (on the level of genera and families). This is associated with not only the climatic differences, but also with the fact that the extensive marine basins of both the Boreal and Tethyan realms have been characterized by diverse facies settings, namely shallow lagoons, areas of the inner and outer shelf, epicontinental depressions and troughs. This habitat variety has accordingly resulted in the existence of diverse benthic foraminiferal assemblages (Kuznetsova *et al*. 2001). One more important factor is the difference in the range of endemicity. Endemic taxa of higher rank (genera, families, orders) dominate in the foraminiferal assemblages of the Tethyan Belt, whereas in the Panboreal Superrealm the range of endemicity manifests itself at the level of genera and species and reaches exclusively the species level in the Arctic Realm (Kuznetsova *et al.* 2001).

The adjacent areas, where faunas of both southern and Boreal-Atlantic types are discovered, have assumed great importance for correlation between the foraminiferal assemblages of different biochores (for terminology see: Westermann 2000; Meledina *et al.* 2001; Zakharov *et al.* 2003). Among such territories is the Dnieper-Donets Basin located at the interface between two paleogeographical realms: the Mediterranean and the Boreal-Atlantic. Two foraminiferal assemblages of varying composition were reported by Pyatkova (1974) within the Volgian deposits. The Boreal representative foraminiferal assemblages, including those with

the index species established for the stratotype of the Volgian Stage, occurred together with typical Volgian ammonites within the northern slope sections. The *Lenticulina segregata* assemblage was distinguished within the Lower Substage of the Volgian Stage. The characteristic species of the beds are: *Ammobaculites haplophragmoides* Furssenko and Poljenova, *Lenticulina segregata* K. Kuznetsova, *L. postkarlaensis* K.Kuznetsova, *L. sokolovi* K. Kuznetsova, *L. infravolgensis* (Furssenko and Poljenova), *L. hyalina* (Mjatliuk), *Marginulina nupera* K. Kuznetsova, *M. buskensis* Bielecka and Pożaryski, *Vaginulinopsis rectus* (K. Kuznetsova), *Citharina raricostata* (Furssenko and Poljenova), *C. brevis* (Furssenko and Poljenova), and *Epistomina gorodistchensis* (Dain). Above those is the Middle Volgian *Lenticulina ornatissima* assemblage, containing the following characteristic species: *Ammobaculites infravolgensis* Mjatliuk, *Flabellamina lidiae* Furssenko and Poljenova, *Lenticulina ornatissima* (Furssenko and Poljenova), *L. infravolgensis* (Furssenko and Poljenova), *L. kasanzevi* (Furssenko and Poljenova), *Marginulinopsis embaensis* (Furssenko and Poljenova), *Saracenaria pravoslavlevi* Furssenko and Poljenova, *Citharina virgatis* (Furssenko and Pojenova), *Geinitzinita nodulosa* (Furssenko and Poljenova), and *Marginulina striatocostata* Reuss. The Upper Volgian deposits do not contain microfaunal remains and have been characterized by a macrofauna which is as yet imperfectly studied.

A typical Tethyan foraminiferal assemblage has been reported from the Middle Volgian sections of the central part of the Dnieper-Donets Basin; it is widely distributed in the Crimea, the Caucasus, Southern France, Italy (Pyatkova 1974; Kuznetsova 1977, 1979). The foraminiferal assemblage includes mainly benthic calcareous secreted-agglutinated forms: numerous representatives of the genus *Charentia* (*Charentia ordinaria* Pjatkova, *C. majuscula* Pjatkova, *C. compacta* Pjatkova), as well as calcareous forms (*Quinqueloculina mitchurini* Dain, *Guttulina pseudocruciata* Dain, *G. dogieli* Dain, *Trocholina solecensis* Bielecka and Pożaryski, *Turrispirillina amoena* Dain) and less numerous *Lenticulina* and *Planularia*.

The comparision of the foraminiferal assemblages from the central part of the Dnieper-Donets Basin with those from the northern slope of the Caucasus has proved the similarity of the generic compositions of these assemblages, except for the genus *Charentia*. The *Trocholina* ex gr. *solecensis, Nubecularia mazoviensis* assemblage has been recorded from the Middle Substage of the Volgian Stage within the Near-Terek area sections (Makaryeva and Matsieva 1980). The foraminiferal assemblage includes *Spirillina* aff. *kubleri* Mjatliuk, *S. italica* Dieni and Massari, *Turrispirillina* ex gr. *amoena* Dain, *Trocholina* ex gr. *alpina* (Leupold), *T.* ex gr. *nodosa* Seibold, *Nodosaria* sp., *Triplasia* sp., *Lingulina* sp., *Lenticulina* aff. *hyalina* Mjatliuk, *L.* ex gr. *cultrata* Montfort, *L.* aff. *muensteri* Roemer, *Ophthalmidium* aff. *dilatatum* Paalzow, *Quinqueloculina* ex gr. *mitchurini* Dain, *Orbignynoides* sp., and *Guttulina* sp. Additionally, the alga *Clypeina jurassica* Favre co-occurs with foraminifera.

The recent data by Voznesenskiy *et al.* (2002) on Jurassic and Cretaceous foraminiferal assemblages enable us to compare, at the generic level, the foraminiferal assemblage from the central part of the Dnieper-Donets Basin with the assorted foraminiferal community of the south-eastern territory of the Lesser Caucasus. Foraminiferal assemblages with a Tethyan composition occur in the Tithonian deposits of the Kafanian district of the Caucasus; they include *Saccammina* sp., *Everticyclammina* ex gr. *virguliana* Koechlin, *Pseudocyclammina lituus* (Yokoyama), *Melathrokerion spirialis* Gorbatchik, *Stomatostoecha* sp., *Charentia evoluta* Gorbatchik, *Textularia alexanderi* (Laliker), *Gaudryina bucowiensis* Cushman and Glazewski, *Lenticulina* sp., *Dentalina nana* Reuss, *Pseudonodosaria humilis* (Roemer), *Trocholina alpina* (Leupold), *T. elongata* (Leupold), and others.

In conclusion, it has to be admitted that at present there is no possibility of precise correlation of the Upper Volgian Substage with the Tithonian – Berriasian. We have found no information available on finds of correlative species in the Upper Volgian and Tithonian – Berriasian assemblages.

SUMMARY

The material reported above permits the following conclusions to be made:

1. In the south-east of Western Siberia two zones with *Pseudolamarckina* have been established: the *Pseudolamarckina lopsiensis* Zone within the Late Kimmeridgian deposits and the *Pseudolamarckina* sp. assemblage corresponding to the Early Volgian, and the *Pseudolamarckina voliaensis* Zone from the Subarctic Urals.

The Middle Volgian *Spiroplectammina vicinalis - Dorothia tortuosa* Zone / assemblage can be reliably subdivided into two subassemblages: the lower *Spiroplectammina vicinalis - Saracenaria pravoslavlevi* and the upper *Dorothia tortuosa* subassemblage. The Upper Volgian deposits contain the *Ammodiscus veteranus - Evolutinella volossatovi* Zone.

2. Taxonomic analysis and determination of correlative species permitted precise correlation between the Volgian foraminiferal assemblages within the entire Panboreal Superrealm. The Early Volgian foraminiferal assemblages from Western Siberia are reliably correlatable with the coeval associations from the Arctic Urals and the East-European (Russian) Platform. The Middle Volgian *Spiroplectammina vicinalis - Dorothia tortuosa* assemblage has been traced from the Canadian Arctic Islands (the Deer Bay Formation) and the Baltic Coast in Europe *via* Western Siberia and Northern Kamchatka as far as the Alaska Peninsula. The Early/Middle Volgian foraminifera of the East-European (Volgian) Province are reliably correlatable with the West-European (Portlandian) one. The Late Volgian *Ammodiscus veteranus - Evolutinella volossatovi* assemblage occurs in Western Siberia, in the north of Siberia and in the Arctic Islands, Spitsbergen.
3. The possibility has been demonstrated of correlation of the Lower-Middle Volgian/Tithonian deposits of the Boreal and Tethyan realms by faunas of both southern and Boreal-Atlantic types distributed within the deposits of the Dnieper-Donets Basin. The comparison of the foraminiferal assemblages from the central part of the Dnieper-Donets Basin with those from the northern slope of the Caucasus and the Kafanian District of the Lesser Caucasus proved the similarity of the generic compositions of these assemblages.

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